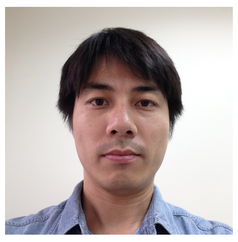
Surface density: a new parameter in the fundamental metallicity relation of star-forming galaxies



Tetsuya Hashimoto and Tomotsugu Goto (National Tsing Hua University)
Email: tetsuya@phys.nthu.edu.tw

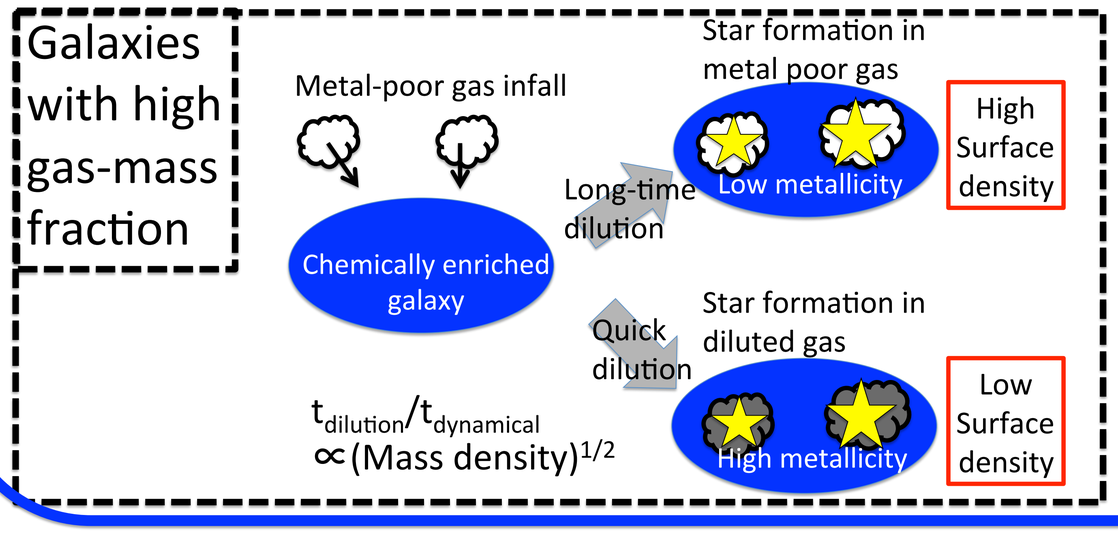
submitted to Nature Scientific Reports

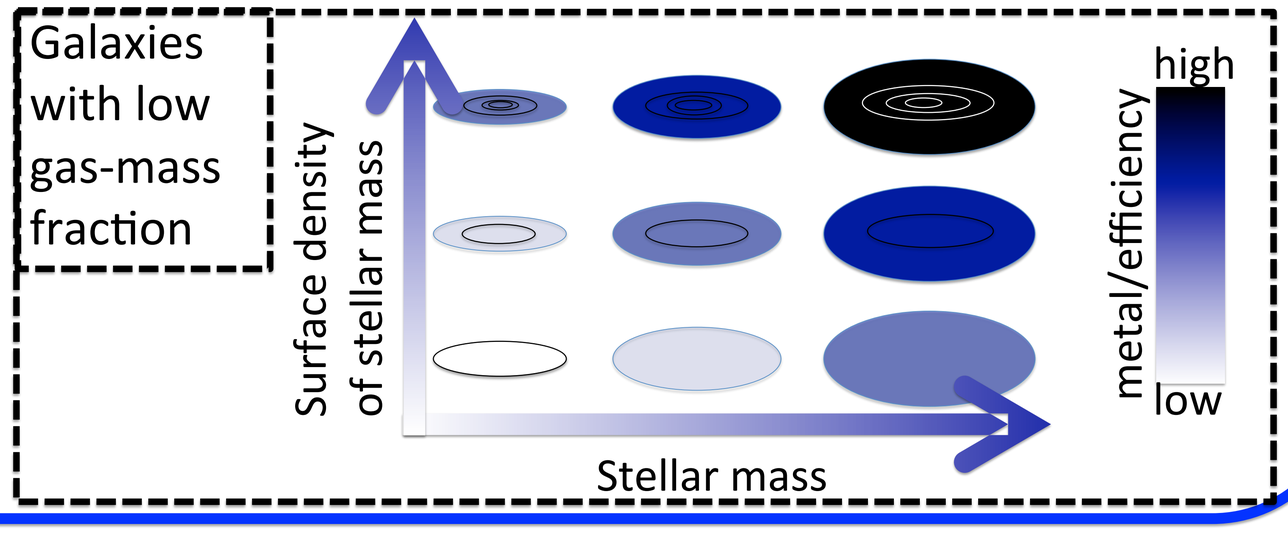
Abstract

We show here that a fourth parameter, the surface density of stellar mass, reduces the dispersion around the fundamental metallicity relation (FMR). In a principal component analysis of 29 physical parameters of 41,338 star-forming galaxies, the surface density of stellar mass is found to be the fourth most important parameter. The new four-dimensional fundamental relation forms a tighter hypersurface that reduces the metallicity dispersion to 50% of that of the FMR.

Conclusion

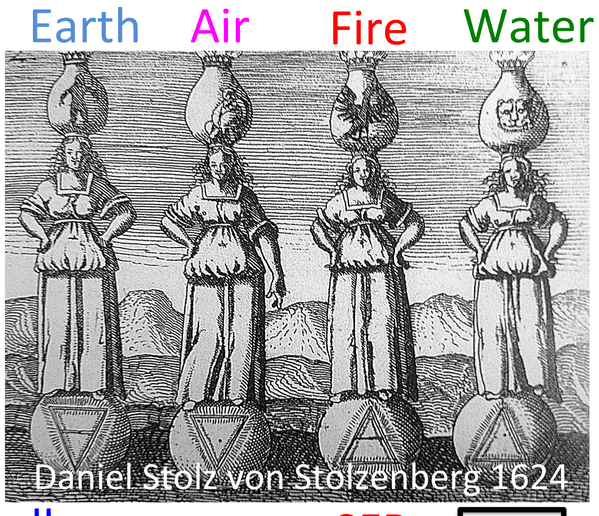
Principal component analysis provides us a quantitative way to select most important physical parameters to govern the physics of star-forming galaxies. The negative and positive correlations between metallicity and surface density of stellar mass cause the dispersion around the molecular-gas FMR. The dilution time scale of gas inflow and the star-formation efficiency can explain the observational dependence on surface density.





1. What is the 4th parameter?

Earth Air Fire Water



Stellar mass SFR Metallicity ?

2. Method

Principal component analysis was conducted for 29 physical parameters of SDSS 41,338 SF galaxies. The resulting 'factor loading' is a fractional contribution of each parameter to the total distribution of data points, indicating the quantitative importance. The parameters are listed below in order of the value of factor loading, which are categorized into 6 groups. Highlighted parameter is top one in each group, analyzed further in the right-hand section.

MASS		METAL		ACTIVITY	
M_*	①Stellar mass	Z_{metal}	④Metallicity	M_{H2}	③Molecular gas mass
Mi	i-band abs. mag	M_{metal}	Metal mass	SFR	Star-formation rate
Mz	z-band abs. mag	Av	Dust extinction	Mu	u-band abs. mag
Mr	r-band abs. mag			sSFR	Specific SFR
Mg	g-band abs. mag			M_{HI}	HI gas mass
M_{virial}	Virial mass			g-r	Color
σ	Velocity dispersion			D4000	4000Å break
M_{igas}	Ionized gas mass			$EW_{H\alpha}$	Hα equivalent width

SIZE/MORPHOLOGY		ENVIRONMENT		OTHER	
ΣM_*	②Surface density of M_*	M_{halo}	⑥Dark matter halo mass	q	④Ionization parameter
r_{half}	Half light radius	δ_5	Galaxy number density	z	Redshift
Σ SFR	Surface density of SFR			n_e	Electron density
r_{disk}	Disk radius				
B/T	Bulge-total fraction				

Labeled number is ranking of the factor loading among top-one parameters in 6 groups.

3. Results

The combination of stellar mass, metallicity, molecular-gas mass, and surface density of stellar mass shows the tightest fundamental relation, indicating that the surface density of stellar mass is the 4th most important parameter (top panel). The reduction of the dispersion around the relation is predominant in metallicity axis (middle panel). The correlations between metallicity and the 4th parameter, which depends on the gas-mass fraction, are attributed to the dispersion around the 3D relation (bottom panel).